Two Dimensional Liquids: Studies At Different Length Scales

Abstract: Patterns form in two dimensional (2D) binary mixtures, with long-term instability, at non-equilibrium. A mixture of dodecanethiol-capped Au nanoparticles (AuNPs) and the amphiphilic fatty-acid Stearic Acid (CH₃(CH₂)₁₈COOH), spread as a monomolecular layer on water, is observed with Brewster Angle Microscopy (BAM) to form a stable, reproducible and extensive high node density (n) quasiperiodic network of AuNP clusters through de-mixing which changes over time to a lower n, aperiodic state of almost perfect circles, both patterns being spatially chaotic with characteristic Lyapunov exponents. Further, the nanoparticle-monolayer (F_NMA) and monolayer-monolayer (F_MMA) lipophilic attraction are progressively increased by increasing the number of -CH₂ groups in the fatty acid (CH₃(CH₂)ₙCOOH) monolayer. Pattern morphology, over 6 hours, reveals three stages in evolution, lamellae (λ state) followed by a high n network (ν state) and finally low n rings (ρ state) of Au nanoclusters evolving from an initial unsegregated state. Increasing F_NMA alongwith F_MMA delays the states, playing role of a viscous drag. Mean square fluctuation of BAM intensity, over time, reveals growth of a sub-diffusive regime (Hurst exponent < 0.5) at the intermediate length scale coinciding with emergence of the ρ state, with the growth being slower for stronger F_NMA and F_MMA, the interactions acting as control parameters in time structuring the spatio-temporal patterns.

Transitional domain patterns are observed during liquid disordered (L_d) to liquid ordered (L_o) phase transition in Myristic Acid (CH₃(CH₂)₁₄COOH) monolayers as the critical point T_c is approached from below. Macroscopically, T_c is estimated from the vanishing of the order parameter, at ≈ 38°C. Mesoscopically, domain morphology in the L_d-L_o coexistence regime passed from stable circular domains and a sharp peak in power spectral density function (PSDF), to stable dendritic domains and divergence of the correlation length at T_c, with a pre-critical regime over ≈ 8°C below T_c characterized by fluctuations in the order parameter, unstable dendritic domains, proliferation of small domains, multiple peaks in PSDF and peak q fluctuating with temperature. T_c is found to be consistent at ≈ 38°C from both isotherm and microscopy. Scaling behavior of the transition follows the 2D Ising model.

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